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AN ANALYSIS OF ENGINEERING AND TECHNICAL SERVICES IMPACT ON MAINTENANCE THROUGHPUT

by

Erik Thompson

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Principal Advisor: Roger D. Evered

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The aim of this thesis is to assess the possible effect of Engineering and Technical Services (also known as tech reps) on the maintenance throughput of aircraft components on automatic test equipment (test benches). Correlation techniques and multiple regression models, one for shore-based test equipment and one for afloat-based test equipment, are used to adress the primary question asked in this thesis: Can we measure the effect of Engineering and Technical Services on the throughput rate of aviation depot level repairable items serviced by automatic test equipment (ATE)? The analysis concludes that the effect of Engineering and Technical Services can be demonstrated both in the case of shore-based test benches, and ship-based test benches, although the results are not strong enough to base general conclusions. The study also demonstrated that the techniques of correlation and multiple regression were useful in indicating other relationships. Further research is recommended to more conclusively assess the effect of tech reps in the maintenance arena.

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Erik Thompson
Lieutenant, Supply Corps, United States Navy
B.S., University of the State of New York, 1984

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Author: ______________________
Erik Thompson

Approved by: ______________________
Roger D. Evered, Principal Advisor

____
Neil E. Seiden, Associate Advisor

____
David R. Whipple, Chairman
Department of Systems Management

ABSTRACT

The aim of this thesis is to assess the possible effect of Engineering and Technical Services (also known as tech reps) on the maintenance throughput of aircraft components on automatic test equipment (test benches). Correlation techniques and multiple regression models, one for shore-based test equipment and one for afloat-based test equipment, are used to address the primary question asked in this thesis: Can we measure the effect of Engineering and Technical Services on the throughput rate of aviation depot level repairable items serviced by automatic test equipment (ATE)? The analysis concludes that the effect of Engineering and Technical Services can be demonstrated both in the case of the shore-based test benches, and ship-based test benches, although the results are not strong enough to base general conclusions. The study also demonstrated that the techniques of correlation and multiple regression were useful in indicating other relationships. Further research is recommended to more conclusively assess the effect of tech reps in the maintenance arena.

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LIST OF ABBREVIATIONS AND ACRONYMS

AIMD	Aircraft Intermediate Maintenance Department
AMSU	Aeronautical Material Screening Unit
ASO	Aviation Supply Office
ATE	Automatic Test Equipment
AVDLR	Aviation Depot Level Repairable
AWP	Awaiting Repair Parts
EOTS	Electro Optical Test Set
ETS	Engineering and Technical Services
EXREP	Expeditious Repair
FLIR	Forward Looking Infrared System
GPRA	Government Performance and Review Act of 1993
LRCA	Local Repair Cycle Area
MDU	Material Delivery Unit
NAESU	Naval Aviation Engineering Service Unit
NALDA	Naval Aviation Logistics Data Analysis System
NIIN	National Item Identification Number
NRFI	Not Ready For Issue
OMB	Office of Management and Budget
RCU	Requisition Screening Unit
RFI	Ready For Issue
SLU	Stock Locator Unit
SSU	Supply Screening Unit
TAT	Turn Around Time
TRU	Technical Response Unit
WUC	Work Unit Code

I. INTRODUCTION

A. BACKGROUND

Measurement of performance is common throughout all facets of life. Measurement is accomplished in many ways, each individually adapted to the situation at hand. In the past few decades measurement of performance has taken on a new significance in business and government. Emphasis on "hard figures" to show progress, prove a point, or by request, is a requirement in virtually all matters which involve financial considerations. The benefit of the use of measured parameters in decision making problems is obvious. It enables a comparison of some sort to be made, or may make the cost benefit analysis the deciding factor. The mortgage lender probably would not consider granting a loan to a person without first examining that individual's credit record and income/debt ratios. The consideration of financial ratios and similar mathematical measures is a rather straightforward affair which produces readily useable information. This information can be easily compared to similar information from a competitor or to a standard set of decision parameter values. Decisions and policy can then be made from this information with greater confidence in the objectivity of the performance data (provided the data was gathered appropriately).

Measurements can be good or bad depending upon the parameter to be measured and the methods chosen to define the parameter. A good measurement is likely when the entity is clearly defined and where the method is explicit, logical, defensible, repeatable, and presents the desired parametric data in a useable form that is useable for the decision maker(s). A bad measurement may be worse than just bad data (or the wrong parameter). It may mislead the decision maker into the wrong conclusions, resulting in bad

policy and decisions. Incorrect conclusions can be especially disastrous in the military.

The measurement of performance in government is a problem because the output is not very well defined. In examining the output of the local Social Security office or welfare agency the measure of productivity may be number of cases handled per day or hour. Case volume is very misleading because actual productivity (the performance on each case) cannot be measured in this way. Hours spent working on a continuous process are similarly a poor measure of productivity. The time itself means little beyond labor and overhead costs. What was actually accomplished in that time period is the true measure of productivity. Actual accomplishment can then be compared to the cost of production and a cost/benefit comparison can then be made.

In government the cost/benefit study can be difficult because of the problem of quantifying the benefit produced. This thesis will address an example of this very problem by developing a measurement method that will lead to value-added determinations for Engineering Technical Services (ETS) in Naval Aviation (specifically in the Naval Aviation Engineering Service Unit). Quantification of value-added is important in the government because the customer (taxpayer) should get full value for each dollar spent. Full value is particularly important in today's fiscal climate of shrinking budget resources. The <u>concept of being required to prove an agency's worth is fairly new</u>, and will hopefully help streamline some of government's functions.

The Government Performance and Results Act (GPRA)of 1993 is major recognition of the need for a tangible performance measurement of benefit gained per dollar spent. Hearings conducted by the Congress on the matter of government performance had produced three findings. They were:

- waste and inefficiency in Federal programs undermine the confidence of the American people in the Government and reduces the Federal Government's ability to address adequately vital public needs;

- Federal managers are seriously disadvantaged in their efforts to improve program efficiency and effectiveness, because of insufficient articulation of program goals and inadequate information on program performance;

- Congressional policymaking, spending decisions and program oversight are seriously handicapped by insufficient attention to program and results. (Government Performance and Results Act of 1993)

To rectify these problems the Act spelled out provisions to:

- Require each Federal agency to submit to the Office of Management and Budget (OMB), beginning in 1997, a five year strategic plan for agency programs, to be updated at least every three years.

- Direct the Federal Government to submit to Congress, starting in FY99, an annual performance plan as part of the Budget of the United States.

- Authorize OMB to waive certain administrative procedure requirements in return for managerial flexibility in achieving performance results exceeding original goals.

- Establish Federal agency pilot projects on performance plans and reports, managerial flexibility, and performance budgeting. (Government Performance and Results Act of 1993)

The Department of Defense (DoD), along with the rest of the Federal Government, has begun the process of instituting

performance measures for many of its operations. Performance measurement has proven to be a daunting task for many functions which, because of their nature, do not have an easily measured output.

The use of Engineering Technical Services (ETS) by the military is widespread throughout the various aviation, ground, and sea forces. ETS are one of those services used widely that do not have a readily quantifiable output. This has made ETS a tempting target for the budget axe, in spite of the cries of the maintenance specialists that the ETS personnel are often invaluable and almost always helpful. When asked what the ETS actually do, the maintenance person is likely to simply say "He helps to train me and teaches me how to fix my equipment." How do you quantify that? The Naval Aviation Engineering Service Unit (NAESU) is one such operation in the DoD that has asked that question.

NAESU is a field activity of the Naval Air Systems Command and reports directly to the Assistant Commander for Logistics and Fleet Support (AIR-04). It was established in 1942 to develop a pool of skilled technicians to train activities in maintenance on the many new and complicated systems developed during World War II.

Although its name has changed several times in the ensuing years, the mission has remained essentially the same. A NAESU pamphlet states the mission as follows:

> To provide field engineering technical assistance and instruction to naval aviation activities in the installation, maintenance, repair, and operation of aviation systems and equipment.

NAESU operates 37 detachments worldwide, consisting of about 530 civilian and military technicians. NAESU also contracts out for about 1200 technicians from the private sector. The detachments are divided among three regional offices co-located with Atlantic, Pacific, and Reserve

aviation type commanders. These regional offices provide coordination for Engineering Technical Services (ETS), more commonly known as "tech reps". The tech rep spends the majority of his time training military technicians on the operation and maintenance of complex equipment including Automatic Test Equipment (ATE) used in the maintenance of aircraft components. The equipment is located at both shore based and ship based Aviation Intermediate Maintenance Departments (AIMDs). Emergency repairs of such equipment is also a major requirement of their time.

B. RESEARCH QUESTIONS

The thesis looks at the effects of the use of tech reps on throughput rates of a type of aviation maintenance automatic test equipment (known as "test benches"). Specifically, how a tech rep visit affects the AN/USM-629 Electro Optical Test Set (EOTS) test benches utilized in the F/A-18 aviation intermediate maintenance program will be studied.

The study is part of a general research effort begun at the request of the Naval Aviation Engineering Service Unit (NAESU) and conducted by the Defense Resources Management Institute. The research effort is aimed at developing quantitative methods of measuring the effects of the tech rep on maintenance processes and procedures, and logistical effects, including spare parts requirements. The end result of this research program should show what effect, if any, does the use of tech reps have on the combat readiness of Naval Aviation and what is the related cost effect. This particular thesis focuses on a measuring of the effect the tech rep has on the repair and diagnostic processes of aviation components through his work on the test bench system.

1. Primary Research Question

Can we measure the effect of ETS (tech rep visits) on the throughput rate of aviation depot level repairable items serviced by automatic test equipment (ATE)?

2. Subsidiary Research Question

Can a tech rep value-added quantification be made using the developed measurement method?

C. SCOPE, LIMITATIONS, AND ASSUMPTIONS

The scope of this research is focused on what effect, if any, the tech rep has on throughput rates on the EOTS test benches aboard several U.S. Navy Pacific Fleet aircraft carriers and at NAS LEMOORE, California. The EOTS test bench chosen is associated with maintenance performed on the F/A-18 aircraft Forward Looking Infrared System (FLIR).

The limitations to this research are clear in that only one test bench type, generally used on one aircraft type, was chosen for study. The study will be further limited to a small number of high volume test bench serviced items that were selected for analysis on the EOTS. The reasons for limiting the research effort to this extent are that by focusing on a small segment of the aviation maintenance community it is hoped that a viable methodology can be developed and demonstrated clearly and concisely. The small segment of maintenance data will make data collection more straight-forward and specific, especially when talking and dealing with members of the aviation community, and when manipulating the not-user-friendly Naval Aviation Logistics Data Analysis system (NALDA). The small data segment is also manageable given the time constraint for this study.

Some assumptions must be made when performing research using data gathered and recorded by others. This study is no exception. To that end all data extracted from the NALDA was taken at face value, and that same caveat is applied to

the various reports generated by the tech reps and technicians themselves. It should be remembered that the data base used is a compilation of data extracted from maintenance forms filled out by the technicians after job completion. Some errors are no doubt contained in the data base due to simple human error and carelessness.

D. METHODOLOGY

One of the most difficult tasks in this study has been developing a method to reveal any tech rep effects on the equipment they work with. After several discussions with tech reps and aviation maintenance officers stationed at the AIMD at NAS LEMOORE, it was decided that a possible measurement avenue lies in investigating what happens to ATE throughput when a tech rep visits a ship with test bench problems.

The thesis methodology is a new approach to the measurement of any benefit contributed by the tech rep and is a several step process. The basic steps include:

- Choosing an ATE based both ashore and aboard ship;
- Selecting a shore based AIMD for analysis and comparison with several afloat AIMDs;
- Selecting several high volume items tested on the selected ATE;
- Collecting throughput data for the selected items from the NALDA;
- Selecting parameters for correlation analysis and setting up regression models for the shore based and afloat based ATE;
- Checking for relationships between throughput rates and tech rep involvement with an ATE;

E. PREVIOUS WORK

A literature search was conducted in the area of measurements of the effectiveness of tech rep type services with the result being that no previous documented research was found. There is much work documented on the need for tech reps and similar types of services (Blanchard, 1994, p.316). One study went so far as to include tech reps in the list of Integrated Logistics Support elements (Colon, 1994, p.38). So far as we could ascertain, there has not been documented work done on the actual measurable benefit received by an organization, either military or civilian, employing tech reps. This is surprising given the cost of engineering technical services (for example, the NAESU budget for fiscal year 1995 is approximately 150 million dollars).

F. THESIS STRUCTURE

The thesis is divided into five chapters. The first and second chapters are basically introductory and background material on the need for measurement techniques to validate effective utilization of resources, structure and method for this thesis, and the associated supply system for the aviation depot level repairable items which are part of the subject of analysis. The third chapter goes into detail on the methodology used and the problems encountered in using it. The fourth chapter describes the actual analysis done to test the methodology while the fifth chapter draws conclusions and makes recommendations for further work.

G. SUMMARY

Chapter I provides background on the research questions and why they were chosen. The measurement of performance by government components is a relatively recent requirement,

dictated by law and fiscal responsibility, and is for many military units a difficult undertaking. The thesis structure and the basic method used in the thesis analysis is briefly described, and will be evaluated for its viability as the main thrust of this research.

II. SUPPLY RELATIONSHIPS WITH AUTOMATIC TEST SYSTEMS

A. INTRODUCTION

The process of repair of items at the Aviation Intermediate Maintenance Department (AIMD), both afloat and ashore, is an administratively intensive one. The sheer variety and volume of repair parts carried at Naval Air Stations and aboard aircraft carriers demand accurate accounting of items on the shelf and in the repair or replacement process. The financial implications of poor repair parts management are enormous.

The price of a repairable item in the military supply system is a two step affair. There exists a "gross price" and a "net price" for each repairable.

The <u>gross price</u> is the price that is charged to the command's operating budget for a new or rebuilt item when there is no "Not-Ready-For-Issue" item (NRFI; an item in need of repair by a depot level facility) item to turn in along with the requisition for the new one.

The <u>net price</u> is the charge to the operating budget for a new or rebuilt item when the command turns in a NRFI item (of the stock number) with the requisition for the new one. The net price is generally much lower than the gross price, and in the case of some items may amount to tens of thousands of dollars in differences (for example, a tactical navigation receiver used in some helicopters has a net/gross price <u>difference</u> of over $65,000 per item).

In addition to the difference between net and gross price on requisitioned items, there is the difference in the price of repairing an item locally and ordering a new item, whether at net or gross price. The price difference may also add up to many thousands of dollars per item, even when the cost of materials, labor and, overhead are added in.

This large difference creates a powerful financial incentive to repair locally all items that are within the capability of the AIMD. The local Supply Officer and his colleague, the AIMD Officer, must determine the repair and ordering policies that they will follow in order to optimize the operational readiness and financial impact that repairable items have on the local aviation operation.

The cost savings of local repair must be balanced against operational need, particularly when an Automatic Test Equipment (ATE) is malfunctioning or there is an operator training problem. Although it is very expensive to order replacements for repairables, this option, or possibly even cannibalization from other aircraft, will be done to keep flight operations at an acceptable level. It is clear from this discussion that the cost of a broken ATE or insufficiently trained operators is very high and must be kept at an absolute minimum. The only alternative to a nonfunctional ATE (equipment and/or operator problem) is a larger stock of repair parts or a very steady and reliable logistics pipeline. Such a situation may prove very difficult in many remote areas of the world.

The processing of aviation depot level repairable (AVDLR) items through the ATE is documented and administratively controlled jointly by the Supply Department and the Aircraft Intermediate Maintenance Department. The development of performance and management statistics is a direct result of the use of various supply and maintenance action forms. A basic understanding of the flow of AVDLR's through the Supply Department and the AIMD is helpful for the analysis and interpretation of data described in Chapters IV and V.

B. AVIATION DEPOT LEVEL REPAIRABLE PROCESSING

The administrative process of sending an AVDLR through the test bench is detailed in OPNAVINST 4790.2E and begins with initial receipt of the item from the customer. In general, with an established weapon system (in this case the F/A-18) the Not Ready For Issue (NRFI) AVDLR is turned in and a Ready For Issue (RFI) item is issued to the customer. The basic steps of the process and the units involved are listed below and are illustrated in Figure 1 (taken from OPNAVINST 4790.2E).

1. Requisition paperwork is turned in by the customer to the Requisition Control Unit (RCU). The requisition is logged in and forwarded to the Technical Response Unit (TRU).

2. The TRU researches the item for interchangeability, substitutes, and next higher assemblies. This step is not always required.

3. The Stock Locator Unit (SLU) locates an RFI item in a storage location and passes the requisition to the Material Delivery Unit (MDU).

4. The MDU actually delivers the item from the storage location to the customer.

5. The NRFI turn in item is turned in to the Supply Screening Unit (SSU) where it is recorded and sent to the AIMD.

6. The AIMD inducts the item into the Aeronautical Material Screening Unit (AMSU) where it placed in the que for testing and repair. The AIMD then utilizes test benches to troubleshoot and repair the item.

7. The now RFI item is returned to the SSU and placed in the Local Repair Cycle Area (LRCA) for storage until needed for issue (see Figure 2).

The whole process is monitored and recorded using various supply and maintenance documents and databases. The repair cycle is also thoroughly documented in the NALDA, and

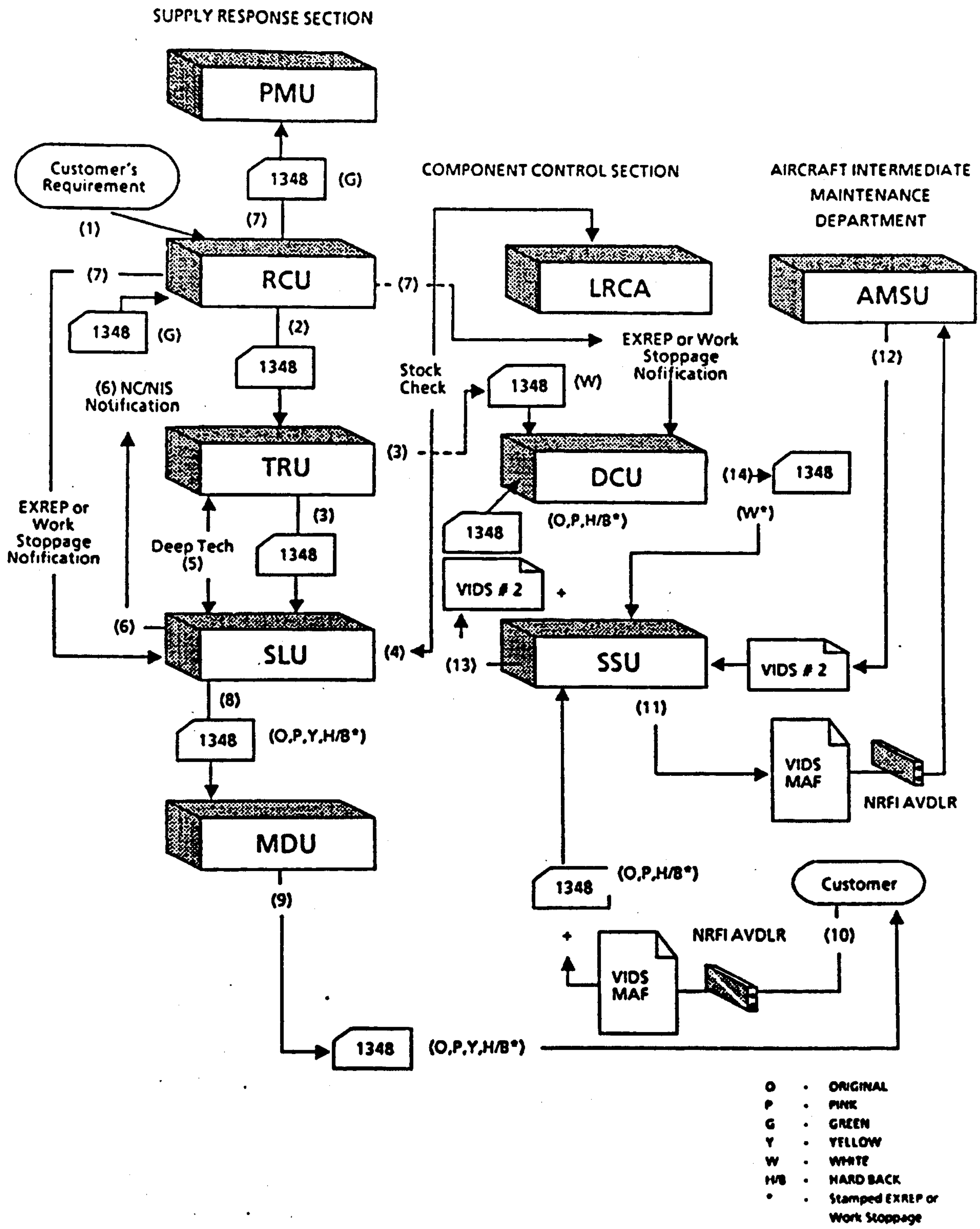

Figure 1. AVDLR Supply Process. (From OPNAVINST 4790.2E.)

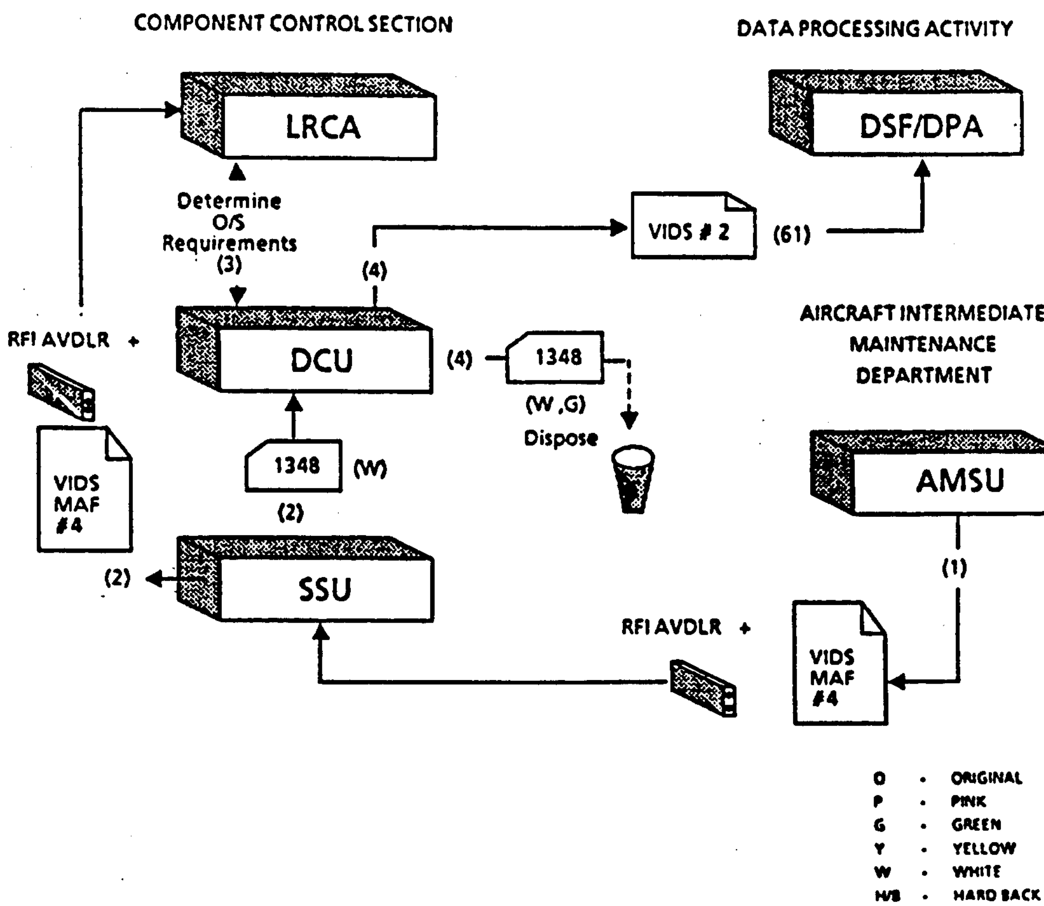

Figure 2. RFI Return From AIMD. (From OPNAVINST 4790.2E.)

in various Aviation Supply Office (ASO) databases.

In the event that there is not an RFI available for issue then there are three options. The item may be requisitioned from another activity (with the NRFI item then turned in to a repair depot) or the NRFI item may be classified as a work stoppage or expeditious repair (EXREP) item. A work stoppage or EXREP item will be placed at the head of the que for testing and repair by the AIMD. The goal is of course to return the item to RFI condition as quickly as possible and to issue it to the customer.

A factor that can impact AVDLR availability is the length of time that the item is awaiting repair parts (AWP). AWP in many situations adds significant time to the turn around time (TAT) or throughput for an item and therefore is taken into account in the analysis in the thesis.

C. SUMMARY

The supply system utilized in the processing of AVDLR's is detailed and thorough. Each item goes through several steps (or units) to ensure it is properly monitored, that useful statistical data is obtained, and most importantly, that the best possible customer support is provided. There are several avenues available for the completion of the requisition. These are ordering a new item from the supply system (turning the NRFI item to the depot, also called a BCM requisition), receiving an RFI item from the local Supply Department (one which has been repaired by the AIMD), or testing and repairing the original NRFI AVDLR (EXREP or work stoppage). The avenue used depends upon the criticality of the situation and local maintenance and fiscal management policies.

III. METHODOLOGY

A. INTRODUCTION

The general question asked when discussion of this thesis began was "How can we measure the worth of a tech rep?". I personally have had many experiences with tech reps and have never doubted their value in training personnel and repairing equipment that the technicians could not. It can be said that tech reps fix "broken gear and broken personnel". How might this be objectively demonstrated and quantified for someone who has not had the same experience? More to the point, how can a value be determined for the services provided by tech reps?

In the case of tech reps in the Naval Aviation Engineering Service Unit (NAESU), which was chosen for this particular study, many of the tech reps specialize in Automatic Test Equipment (ATE) used for testing and repairing aircraft components. It is intuitive that if an ATE (test bench) were to be "down" for more than a few days, then the components serviced by the test bench would not be repaired and a bottleneck would develop in the repair queue. If the throughput rates of these repairable components were normally very high, then the likelihood of locally running out of these components would go up even if demand remained fairly constant and assuming no resupply action is taken. If there were a steady resupply operation then the problem would evolve from one of locally being out of stock to one of being unduly dependent on the supply pipeline.

Recalling the discussion on gross/net price differences on AVDLRs from Chapter II, it could turn into a very expensive test bench breakdown indeed if all replacement components had to be procured via the supply system instead of being repaired locally. The problem may become prohibitively expensive if one takes into account transportation costs for the supply

pipeline.

This line of questioning has led to the idea of measuring the effect of tech reps on test bench throughput. If a measurable relationship can be shown to exist between the effects of tech reps and the throughput rates of the test bench, then it might be possible to further analyze this relationship for its effects on required stock levels of Aviation Depot Level Repairables (AVDLRs) at shore stations and aboard ship. This could then conceivably lead to calculable financial savings by the use of tech reps.

The techniques chosen to assess this relationship are the correlation and multiple regression methods, using a personal computer. These methods were chosen because the data are numerical in nature and could indicate any possible relationships between sets of data involved with Electro Optical Test Set (EOTS) test bench throughput. These are user-friendly methods when using a personal computer with any of several spreadsheet programs (LOTUS, EXCELL, QUATTRO PRO, etc.) or statistical packages (such as SPSS), and the results are readily replicated.

B. SELECTION OF AN AUTOMATIC TEST EQUIPMENT TEST BENCH

The selection of the test bench for study was the first step in data gathering for this thesis. The considerations for selection were primarily volume of throughput, location of the ATE both ashore and aboard ship, and tech rep involvement with the system.

A higher volume of throughput, which will provide more data points, is considered critical for valid multiple regression analysis. A larger number of data points will better utilize the correlation and regression methods in finding any discernable relationships in the data.

The location of identical ATEs ashore and aboard ship is important to enable results between the two to be compared.

The actual functioning and diagnostic capabilities of the test bench are deemed not to be important to this particular study.

Tech rep involvement is considered vital to the analysis. The main thrust of the thesis is to devise a method to measure the effect of tech reps on maintenance throughput. Data regarding the tech rep's involvement with the system are therefore a requirement for inclusion in the model.

The Aviation Intermediate Maintenance Department (AIMD) and the NAESU detachment located at NAS LEMOORE were visited and discussions were held with the tech reps and technicians who operate and service the ATEs located there. Based on these discussions, the following list of four candidate test bench types was developed.

- Electro Optical Test Set (EOTS);
- Radar System Test Set (RSTS);
- Hybrid Test Set (HTS);
- ARM 200 Test Bench;

The Naval Aviation Logistics Data Analysis (NALDA) database was then consulted. The component maintenance data were retrieved from the NALDA database for each of the four test bench types.

The NALDA database is a rather extensive maintenance logistics information database maintained at the Aviation Supply Office (ASO) in Philadelphia. It receives input data from the field on virtually all aviation maintenance actions, including maintenance done at AIMDs. The available data at the component level are varied and include such things as average repair times, turn around times, processing times, scheduling times, awaiting parts times, as well as other data. NALDA data are stored only for the previous 18 calendar months, and can be broken down for individual components by National Item Identification Number (NIIN), work unit code

(WUC), and other criteria. NALDA information is available for component maintenance from the service-wide level down to the individual command level.

The wide range of readily available NALDA data is the reason it was chosen as the source of component specific maintenance information. The database itself is not, however, easily accessible. The services of the Quality Assurance Division at AIMD, NAS Lemoore, California, were enlisted to retrieve requested NALDA information via their link with ASO.

Candidate test bench throughput data was retrieved from NALDA for the AIMDs located ashore at NAS LEMOORE, NAS FALLON, and aboard the following aircraft carriers: USS LINCOLN, USS VINSON, USS KITTY HAWK, USS INDEPENDENCE, USS CONSTELLATION, USS NIMITZ, USS AMERICA, USS EISENHOWER, USS SARATOGA, USS WASHINGTON, and USS ROOSEVELT.

Throughput data showed that the Electro Optical Test Set (EOTS) test bench was a good candidate for study based upon the relatively high volume of work done with this bench when compared to the other three candidate test bench types.

C. SELECTION OF TEST BENCH LOCATIONS

Volume of EOTS work center throughput and monthly EOTS tech rep work hours were used as criteria in the selection of the ashore AIMD location. The volume of throughput for the EOTS work center and the number of tech rep visits to each site were the discriminators used in the selection of afloat AIMD locations. The component throughput data for the EOTS test bench made it possible to shorten the list of test bench locations used in the analysis. The amount of NALDA data provided by one shore location and three ship locations were considered to be adequate to test the methodology used in the thesis.

A high volume of EOTS throughput is desirable to provide a large number of data points for use in the correlations and

regressions. NAS LEMOORE and the three ships listed below had the highest EOTS throughput volume of the candidate sites considered.

NAS LEMOORE had the highest number of monthly EOTS tech rep work hours among the two shore stations examined. Among the afloat sites considered the number of tech rep visits to the ships were considered very important to the analysis. The ships chosen had the greatest number of visits by the EOTS tech reps in the period covered by the NALDA data (9308-9501) used in the analysis.

The USS INDEPENDENCE was eliminated from the preliminary list as not being representative of the fleet units after it was discovered that the tech rep servicing that EOTS test bench is permanently stationed aboard that vessel, unlike the other ships who request a tech rep visit only when they feel it necessary. The goal with the ship model was to approximate the typical command that utilizes temporary tech rep assist visits. The final list of test bench sites selected follows:

<u>Ashore</u>:

NAS LEMOORE

<u>Afloat</u>:

USS VINSON
USS LINCOLN
USS KITTY HAWK

D. SELECTION OF SPECIFIC NIIN ITEMS FOR ANALYSIS

With the selection of the test bench type and AIMD locations complete, the next step was to select specific stock numbered items serviced by the EOTS bench for correlation and regression analyses. Selection of specific National Item Identification Number (NIIN) items with higher volumes of throughput were required to facilitate meaningful use of the correlation and multiple regression programs. The EOTS

throughput data for fiscal year 1994, for the entire US Navy and Marine Corps, was sorted according to volume of items serviced.

The top 13 items, identified by National Item Identification Number (NIIN), were selected for analysis in the shore model. Examination of NAS LEMOORE data showed that the EOTS located there had serviced all 13 of the top NIIN items during the FY 1994 period. The specific NIIN items selected for analysis in the shore model are listed below and in Appendix A.

The number of NIIN items selected for use in the ship model dropped to a total of six because some of the ships did not service all 13 of the NIIN items during the 18 month period covered in the NALDA data used. The six selected NIIN items were processed by all three of the ships used in the model. The specific NIIN items selected for analysis in the ship model are listed below and in Appendix B.

Shore NIIN Items	Ship NIIN Items
011861629	011861629
011884089	011884089
011468298	011468298
012900767	012900767
013174521	013174521
011861418	013224279
013224279	
011861619	
011861430	
012711091	
011872208	
012623221	
013174556	

E. DATA QUALITY

During the selection of dependent and independent variables, described below, it was noticed that the data from the Naval Aviation Logistics Data Analysis system did not always sum correctly in the Turn-Around-Time (TAT) formula (see Equation 3.1). One instance of this, for a NIIN item not used in the study, was noticed. The number of days recorded in the data base as average repair times also seems excessive in some cases. The data was taken at face value for the thesis, but there are undoubtedly some errors in them, because the data are derived from manual forms filled out by the work center personnel. Data entry for the NALDA would be a worthwhile subject for further study.

F. SELECTING THE DEPENDENT VARIABLE

The problem now arose as to which specific components of throughput data for the NIIN items to analyze, which variables might affect the throughput data component selected for analysis, and how to interpret the results. The desire was to select the most significant variables indicating any relationships between the tech reps' activities and maintenance throughput.

The <u>ideal tech rep visit</u> effectively trains work center personnel, both ashore and shipboard, in operation and repair of the ATE. Intuition says that the throughput for a NIIN item might be measurably improved by the visit of a tech rep to an EOTS location. <u>Better training</u> of personnel and <u>properly maintained equipment</u> should conceivably <u>result</u> in a measurably <u>higher rate of throughput</u> for a specific NIIN item. Selection of a representative component of test bench throughput was now needed for use as the <u>dependent variable</u> for use in correlation studies and in the regression models for the ship and shore models.

The first dependent variable candidate considered was

Turn-Around-Time (TAT). Blanchard describes TAT as the time taken for an item to go through the complete cycle from removal from operation to repair to the spares inventory (Blanchard, 1992, p.18). The TAT selection was eventually ruled out as being too general because the EOTS tech reps studied in this case do not have control over matters of NIIN item removal, induction into the repair cycle (see Chapter II), and time spent awaiting replacement parts. These are all components of TAT. A look at the TAT equation used by the NALDA is appropriate at this point.

$$TAT = PRO + SHED + REP + AWP$$

where:

TAT = Turn-Around-Time (time between removal of the component from operation and its placement in the RFI spares inventory);

PRO = Processing time (time between actual removal of component and its turn in to AMSU);

SHED = Scheduling time (time between receipt by AMSU and induction to a work center for repair);

REP = Repair time (time between induction to a work center for repair and completion of RFI/BCM action, less any AWP time);

AWP = Awaiting parts time (time during which component was not being worked on while awaiting parts not available locally).

Equation 3.1

The component of TAT deemed most likely to show any relationship with tech rep action is <u>repair time</u>. The reasoning behind this statement is that the training, troubleshooting skills, and experience of the tech rep conceivably have a direct effect on the time that work center

personnel require to perform repair and diagnostic procedures on the EOTS test bench. That should be true whether the tech rep conducts training on the operation of the EOTS or helps the operators repair a down bench (one that has failed in some way). A tech rep's visit to an EOTS location should have the effect of reducing the average repair time required to process an item through the bench.

<u>Average repair time data for specific NIIN items were therefore selected as the dependent variable (designated in the models as variable Y_{RT}) for the shore and ship models</u>. The data, listed in days, were obtained from the NALDA database. The data were available for the previous 18 month period of 9308-9501 only (it is updated every month, with the oldest month dropped out). The average repair time data is presented for the months in which there were actual repairs recorded for the specific NIIN item. For a specific NIIN item, over an 18 month period there may be only seven or eight months with average repair time data. The rest of the months with no average repair time data are deleted for that specific NIIN item.

Selection of the parameters independently affecting repair time now had to be made. Independent variable selection was different for the shore model and the ship model in order to account for the difference in the counting of tech rep working hours at the shore station EOTS work center and the counting of EOTS tech rep visits aboard ships.

G. SHORE MODEL INDEPENDENT VARIABLES

The variables conceivably effecting the shore based EOTS work center production process are numerous. Selection of key variables directly effecting the production process generally, and the average repair time in particular.

The shore model independent variables selected were:

1. Tech Rep Hours - Total tech rep working hours in the EOTS work center for a specific month;

2. Specific NIIN Items Processed per Month - Volume of a specific NIIN item processed by a work center in a specific month;

3. Total NIIN Items Processed per Month - Volume of all analyzed NIIN items processed by a work center in a specific month;

1. Tech Rep Hours

Tech rep hours, designated as variable X_1, were obtained from the tech reps using their work time records. The NAESU Detachment is located at NAS LEMOORE and the EOTS tech reps have permanent offices in the EOTS work center. An EOTS tech rep is available in the work center continuously during normal work days. The data attempts to capture the actual hours spent in and around the work center, with time for leave, sickness, and travel subtracted. Since there are two EOTS tech reps assigned to NAS LEMOORE, and the hours were based on a 160 hour work month per tech rep, a normal expected maximum would be 320 hours per month.

2. Specific NIIN Items Processed Per Month

The volume of specific NIIN items processed per month, designated as variable X_2, is important because the average repair time for a specific NIIN item is bound to be affected by the number of occasions per month that item is serviced by the technicians on the test bench. The effect is attributable to both the learning curve effect and to the time constraints the technician is working under. Due to the manner in which NALDA data are presented, the variable includes those items sent through the test bench process, as well as those sent directly to the depot for repair and/or replacement (this process is known as a BCM action, see Chapter II, p. 16).

3. Total NIIN Items Processed Per Month

The total volume of all NIIN items processed through a test bench is included as variable X_3 because of the effect of total work volume on the work time available for specific items. Some of the influence of this variable may be attributable to the learning curve effect since operation of the test bench, even on different components, may increase a technician's proficiency on that test bench for all components serviced across it. Conversely, the processing of many different types of components may also prevent the test bench operator from becoming proficient on specific items.

H. SHORE MODEL

The complete shore model is shown below.

$$Y_{RT} = \alpha + \beta_1(X_1) + \beta_2(X_2) + \beta_3(X_3)$$

where:

Y_{RT} = average repair time;

α = constant;

β_i = coefficients;

X_1 = tech rep hours;

X_2 = specific NIIN items processed per month;

X_3 = total NIIN items processed per month.

EQUATION 3.2

I. SHIP MODEL INDEPENDENT VARIABLES

The data analyzed are for the same period as the data used in the ship model. The independent variables chosen were:

1. Tech Rep Visit - Represents whether or not the tech rep was actually aboard the ship in a specific month;

2. <u>Specific NIIN Items Processed per Month</u> - Volume of a specific NIIN item processed by a work center in a specific month;

3. <u>Total NIIN Items Processed per Month</u> - Volume of all analyzed NIIN items processed by a work center in a specific month;

As with the shore model, there is a large number of variables that can conceivably affect the throughput of a work center (the weather, intelligence of the personnel, etc.). Ship deployment periods were considered as a possible variable but were dropped from inclusion because the ships operate at other times aside from deployment and the tech reps travel to the ships during non-deployment periods also. The variables selected were objective in nature, readily measurable, and seemed most likely to be indicative of any relationships between the tech rep and NIIN item average repair times. The data were analyzed for the most recent 18 month period available in the NALDA database covering the period of August 1993 (9308) through January of 1995 (9501).

1. Tech Rep Visit

Since this is a study on measuring the possible relationships between actual tech rep visits and maintenance throughput then the visit of the tech rep to the test bench location must be assigned a variable. The value of the variable (designated as <u>variable X_1</u>) representing whether or not the tech rep was aboard the ship during any particular month was designated either to be 1 or 0, with 1 representing his presence aboard that particular month, and 0 representing his absence from the ship. The actual hours worked by a tech rep while aboard ship, unlike those ashore, are likely to be much more than eight hours per day because, quite frankly, there is not much else to do aboard ship except work. The tech reps interviewed stated they wanted to get off the ship and return home as soon as the job was complete. Since the

tech rep is not normally aboard (there being the exception of the USS INDEPENDENCE) the value assigned to the Tech Rep Visit variable X_1 is most often 0. Actual tech rep shipboard work hours were not available for study. Hence the difference in the method of assigning values for the tech rep's presence in the shore and ship models.

It should be noted that there were a fairly small number of tech rep visits to the ships during the period covered by the NALDA data. The relatively small number of tech rep visits greatly effected the validity of using correlation and regression methods for the ship model. The matter of the number of tech rep visits is discussed in Chapters IV and V.

2. Specific NIIN Items Processed Per Month

As in the shore model, the volume of specific NIIN items processed per month (designated as variable X_2) is important because the average repair time for a particular NIIN item is likely to be affected by the number of occasions per month that item is serviced by the technicians on the test bench. Due to the manner in which NALDA data is presented, the variable includes those items sent through the test bench process, as well as those sent directly to the depot for repair and/or replacement (this process is known as a BCM action, see Chapter II).

3. Total NIIN Items Processed Per Month

Similar to the shore model, the total volume of NIIN items processed through a test bench (designated as variable X_3) is included as an independent variable because of the effect of total work volume has on the work time available for specific items. Like the shore model, some of the influence of this variable may also be attributable to the learning curve effect since operation of the test bench, even on different components, may increase an operator's proficiency on that test bench for all components serviced across it. It is possible that it may also increase the average repair time

because the variety of components worked on may prevent repetitive learning from occurring.

J. SHIP MODEL

The completed ship model is shown below.

$$Y_{RT} = \alpha + \beta_1(X_1) + \beta_2(X_2) + \beta_3(X_3)$$

where:

Y_{RT} = average repair time for a particular NIIN;

α = constant;

β_i = coefficients;

X_1 = tech rep visit;

X_2 = specific NIIN items processed per month;

X_3 = total NIIN items processed per month.

EQUATION 3.3

K. ANALYSIS USE OF MODELS

The data for the shore model was first examined for correlation between each of the independent variables (X_1, X_2, and X_3) and the dependent variable (Y_{RT}). A regression was then run using all three independent variables (X_1, X_2, and X_3).

In the ship model study, the correlations of relationships between the specific NIIN item average repair times (variable Y_{RT}) and the three independent variables (variables X_1, X_2, and X_3) were examined first. A regression study of the data was made for two items, but overall, the small amount of ship data available did not support continued analysis. This is discussed in Chapter IV.

L. SUMMARY

Chapter III has described the reasoning leading up to the analysis process used. The process of selection of the test

bench type and selection of bench locations was detailed. The selection of parameters for study, variable values assigned, and the effect of each parameter was discussed for both the shore model and the ship model, as well as the sources of the data to be analyzed. The models themselves were described in their applicable sections. The selection and sequence of the analysis was also detailed.

IV. ANALYSIS AND FINDINGS

A. ANALYSIS USING THE SHORE MODEL

The data used for shore model analysis of each NIIN item are presented in Appendix A. The tables present average repair time data (variable Y_{RT})for all months covered by the NALDA data (9308-9501) in which the EOTS work center worked on the specific NIIN item. Corresponding month values for tech rep hours (variable X_1), specific NIIN items processed per month (variable X_2), and total NIIN items processed per month (variable X_3) are also presented for each specific NIIN item.

Some items had average repair times listed for months in which there were 0 specific NIIN items processed (see NIIN item 011861619 in Appendix A for an example). The items for these months were sent to the repair depot after problem diagnosis in the EOTS work center, with the average repair time representing diagnostic time for the specific item (this process is known as a BCM action, see Chapter II).

The analysis was done in a systematic manner. The first step examined correlation between the average repair time, represented by variable Y_{RT}, and each of the three independent variables (X_1, X_2, and X_3). The regression was performed next using all three variables.

1. Shore Model Correlation Study

Correlation data between the dependent variable Y_{RT} and each of the independent variables (X_1, X_2, and X_3) are presented in Table 4.1. The correlation between average repair time and tech rep hours (variable X_1) are negative in 8 out of 13 NIIN items and all 13 have an average of -.15. These data indicate that, in 8 of 13 cases examined, <u>an increase in tech rep hours is related to a decrease in average repair time</u>. Three of the items had strong negative correlations, with values of -0.60, -0.65, and -0.84.

Shore Model Correlation Results

ART = Ave Repair Time
TRH = Tech Rep Hours (X1)
SNV = Specific NIIN Items Processed Per Month (X2)
TNV = Total NIIN Items Processed Per Month (X3)

NIIN Item	ART vs TRH	ART vs SNV	ART vs TNV
011861629	-0.23	0.42	0.42
011884089	-0.41	0.57	-0.10
011468298	-0.16	-0.45	-0.09
012900767	-0.20	-0.13	0.18
013174521	**-0.65**	-0.14	0.31
011861418	**-0.84**	-0.39	-0.08
013224279	0.03	-0.14	0.28
011861619	-0.05	0.07	-0.20
011861430	0.79	-0.41	-0.12
012711091	0.23	0.01	0.06
011872208	0.14	0.37	0.35
012623221	**-0.60**	0.61	-0.11
013174556	0.01	0.11	0.01
Average	-0.15	0.04	0.07

Table 4.1 Shore Model Correlation Results

One item, NIIN item 013174556, had a strong positive correlation of .79. In this specific case, an increase in tech rep hours appears to be related to an increase in average repair time for this NIIN item. A possible cause for this is some design peculiarity of the item, or perhaps data inaccuracies. The actual cause is unknown.

The correlation between average repair time (variable Y_{RT}) and specific NIIN items processed per month (variable X_2) is inconsistent between NIIN items. Six out of 13 NIIN items had a negative correlation value. The values ranged between .61 and -.45 and have an average of .04. Two NIIN items had a correlation value of more than .5. This is an interesting result because one would expect that the learning curve effect associated with working on similar NIIN items would consistently show a reduction in the average repair time for that item.

The correlation between average repair time and total NIIN items processed per month (variable X_3) shows similar results to the specific NIIN items processed per month. Six of 13 cases are negative, with a range of .42 to -.12. The average of the correlation values is .07. The implication here is that the <u>average repair times</u> for the specific NIIN items studied <u>do not display a consistent pattern of change when the volume of throughput is increased</u>. Obviously other factors are at work. Perhaps a larger, more varied data set would show different results.

The net result of the correlation study shows that tech rep hours (variable X_1) has the highest correlation, followed by total NIIN items processed per month (variable X_3), and then by specific NIIN items processed per month (variable X_2). The correlation results definitely show that the time a tech rep puts in on the job has a distinctly negative relationship with average repair time of specific NIIN items.

2. Shore Model Regression Analysis

As one would expect, the regression results follow the same pattern as the correlation study. The regression was run using all three independent variables. The results are presented in Table 4.2.

The magnitude of the values for the tech rep hours coefficient remained small, with 9 of 13 values being slightly negative, with an average value of -.02, and a range of .08 to -.13. The tech rep hours coefficient values indicate a <u>slightly negative relationship between tech rep hours and average repair time</u>, but this effect is greatly overshadowed by the effects of the volumes of specific and total NIIN items processed per month.

The coefficient of specific NIIN items processed per month (variable X_2) has a positive relationship in seven of 13 cases, with an average of .83, and a range of 19.73 to -10.22. The values of the coefficient reflect the inconsistent results found in the correlation of the average repair times with specific NIIN items processed per month. There is not a definite overall pattern, but the range indicates relatively extreme effects, in both directions, upon average repair time.

The coefficient of total NIIN items processed per month (variable X_3) has a positive relationship in six of 13 cases. The average of values is .16, with a range of .78 to -.49. The effect of this coefficient appears to be similar to the effect of the X_2 coefficient, although smaller in magnitude. As in the correlation study, the implication is that the <u>average repair times</u> for the specific NIIN items studied <u>do not display a consistent pattern of change when the volume of throughput is increased</u>.

The significance levels of all three of the variables are rather low, indicating a distinct possibility of randomness, with two exceptions. The significance of the coefficient of tech rep hours (variable X_1) in the case of NIIN item

Shore Model Results For Regression With:
Tech Rep Hours (Variable X1)
Specific NIIN Items Processed Per Month (Variable X2)
Total NIIN Items Processed Per Month (Variable X3)

NIIN	R Sq	X1 Coeff	X2 Coeff	X3 Coeff	X1 Std Err	X2 Std Err	X3 Std Err
011861629	0.25	-0.04	0.56	0.47	0.04	1.89	0.73
011884089	0.48	-0.03	5.43	-0.49	0.03	2.05	0.36
011468298	0.29	-0.05	-10.22	-0.08	0.06	7.49	0.58
012900767	0.08	-0.02	-0.88	0.35	0.05	2.84	0.47
013174521	0.54	-0.13	0.42	0.78	0.04	2.31	0.52
011861418	0.78	-0.07	-4.86	0.48	0.08	13.02	1.97
013224279	0.17	-0.01	-2.95	0.32	0.02	2.91	0.24
011861619	0.11	0.01	1.29	-0.38	0.03	2.59	0.64
011861430	0.64	0.08	-0.22	-0.08	0.04	3.90	0.52
012711091	0.08	0.03	-3.61	0.65	0.11	27.90	3.60
011872208	0.28	0.03	4.06	0.38	0.05	4.58	0.46
012623221	0.58	-0.09	19.73	-0.26	0.10	19.36	0.86
013174556	0.02	-0.02	2.01	-0.01	0.09	5.28	0.77
Average	0.33	-0.02	0.83	0.16			

NIIN	X1 t Stat	X2 t Stat	X3 t Stat	X1 Signif	X2 Signif	X3 Signif	Deg. Frdm
011861629	-1.00	0.30	0.64	0.200	0.400	0.300	14
011884089	-1.00	2.65	-1.36	0.200	0.025	0.100	12
011468298	-0.83	-1.36	-0.14	0.250	0.200	0.450	5
012900767	-0.40	-0.31	0.74	0.400	0.400	0.250	11
013174521	-3.25	0.18	1.50	0.005	0.450	0.100	13
011861418	-0.88	-0.37	0.24	0.250	0.400	0.450	2
013224279	-0.50	-1.01	1.33	0.400	0.200	0.200	9
011861619	0.33	0.50	-0.59	0.400	0.400	0.300	3
011861430	2.00	-0.06	-0.15	0.100	>.500	0.450	4
012711091	0.27	-0.13	0.18	0.450	>.500	0.400	1
011872208	0.60	0.89	0.83	0.300	0.250	0.250	5
012623221	-0.90	1.02	-0.30	0.250	0.250	0.400	2
013174556	-0.22	0.38	-0.01	0.450	0.400	>.500	8

Table 4.2 Shore Model Regression Results

013174521, and the coefficient of specific NIIN items processed per month (variable X_2) in the case of NIIN item 011884089, indicate a very low likelihood of randomness in their results.

The R squared values range from .78 to .02, with an average of .33. The results indicate that the regression accounts for a fairly significant amount of the variation in average repair times, especially in the four cases where R squared is greater than .5. <u>The results of the regression indicate that the specific NIIN items processed per month (variable X_2) has the greatest effect on the average repair time (variable Y_{RT}), followed by total NIIN items processed per month (variable X_3), with tech rep hours (variable X_1) running a distant third</u>. Of the three variables the tech rep hours variable appears to be the most consistent in its effect.

B. ANALYSIS USING THE SHIP MODEL

The data for each NIIN item studied in ship model are presented in Appendix B. The tables present average repair time data (variable Y_{RT})for all months covered by the NALDA data (9308-9501) in which the shipboard EOTS work center worked on the specific NIIN item. Corresponding month values for tech rep visits (variable X_1), specific NIIN items processed per month (variable X_2), and total NIIN items processed per month (variable X_3) are also presented for each specific NIIN item.

As with the shore data, some items had average repair times listed for months in which there were 0 specific NIIN items processed (see NIIN item 012900767 in Appendix B for an example). The items for these months were sent to the repair depot after problem diagnosis in the EOTS work center, with the average repair time representing diagnostic time for the specific item (this process is known as a BCM action, see Chapter II).

The data were aggregated in columns for the three ships in order to facilitate use of the correlation and regression functions of the LOTUS program.

1. Ship Model Correlation Study

The results of correlating average repair time with each of the three independent variables are presented in Table 4.3. The discussion of the ship model results must be prefaced with the comment that the small amount of data makes the results inconclusive. When months for which average repair time data was available was correlated with the independent variables, it was discovered that the few months in which the tech reps made ship visits provided insufficient data points for valid analysis.

The correlation between Average Repair Time and Tech Rep Hours (variable X_1) is negative for two out of six NIIN items and averages -.37. The other four items were not repaired during the months of a tech rep ship visit, so a correlation was not possible. The correlation data indicate that the tech rep's presence reduces the average repair times for both of the two NIIN item cases studied. While both cases show clearly the benefits of the tech rep's visit, having only two NIIN item cases to examine makes it difficult to generalize.

The correlations between average repair time and specific NIIN items processed per month (variable X_2) are strong. Four out of six NIIN item correlations had an absolute value of greater than .4, with an overall average of .32, and one negative value of -.4. Two NIIN items had a correlation value of more than .7. The implication is that the average repair time for a specific NIIN item increases with an increase in the volume of throughput for that specific NIIN item. This is unexpected. One would expect that the learning curve effect associated with working on similar NIIN items would reduce the average repair time for that item.

Ship Model Correlation Results

ART = Ave Repair Time
TRH = Tech Rep Hours (X1)
SNV = Specific NIIN Items Processed Per Month (X2)
TNV = Total NIIN Items Processed Per Month (X3)

NIIN Item	ART vs TRH	ART vs SNV	ART vs TNV
011861629	-0.39	0.44	0.58
011884089	No Visit	0.76	0.40
011468298	No Visit	0.35	0.48
012900767	No Visit	0.73	-0.77
013174521	-0.35	0.33	0.15
013224279	No Visit	-0.40	0.27
Average	-0.37	0.32	0.16

Table 4.3 Ship Model Correlation Results

The correlation between average repair time and total NIIN items processed per month (variable X_3) shows a similar result to that of the specific NIIN items processed per month. All but one of the cases are positive, ranging from .58 to a -.77. The relationship again appears to be that an increase in total work center throughput results in a higher average repair time.

The net result of the correlation study indicates that tech rep hours (variable X_1) has the highest correlation, followed by specific NIIN items processed per month (variable X_2), with total NIIN items processed per month (variable X_3) in third place. The ship model correlations are clear in showing the benefit of tech rep visits, though a larger amount of useable data would be necessary before general conclusions can be drawn.

2. Ship Model Regression Analysis

The use of the ship data in the ship regression model did not yield any conclusive results useful for this thesis, due to the lack of useable data. Table 4.4 presents results of the regression. The two NIIN items run in the regression do indicate that the tech rep visit reduces average repair time aboard ship for those two NIIN items, but the significance levels do not effectively rule out randomness.

C. SUMMARY

Chapter IV has described and documented the actual analysis done on the data collected. The actual data used in each model is discussed, and the correlations and regressions are analyzed. The resulting correlation values and regression results are discussed and possible relationships are examined.

The shore model results, both in the correlation and the regression, show some fairly significant relationships. The <u>hours worked by the tech rep have a definite (although small) negative relationship with average repair time</u>, while the

Ship Model Results For Regression With:
Tech Rep Hours (Variable X1)
Specific NIIN Items Processed Per Month (Variable X2)
Total NIIN Items Processed Per Month (Variable X3)
ND = No Data

NIIN	R Sq	X1 Coeff	X2 Coeff	X3 Coeff	X1 Std Err	X2 Std Err	X3 Std Err
011861629	0.36	-9.49	0.26	2.82	14.97	4.64	2.62
011884089	ND	ND	ND	ND	ND	ND	ND
011468298	ND	ND	ND	ND	ND	ND	ND
012900767	ND	ND	ND	ND	ND	ND	ND
013174521	0.24	-20.65	8.39	-1.02	15.42	6.44	1.60
013224279	ND	ND	ND	ND	ND	ND	ND
Average	0.30	15.07	4.33	0.90			

NIIN	X1 t Stat	X2 t Stat	X3 t Stat	X1 Signif	X2 Signif	X3 Signif	Deg. Frdm
011861629	-0.63	0.06	1.08	0.300	>.500	0.200	11
011884089	ND	ND	ND	ND	ND	ND	ND
011468298	ND	ND	ND	ND	ND	ND	ND
012900767	ND	ND	ND	ND	ND	ND	ND
013174521	-1.34	1.30	-0.64	0.200	0.200	0.300	11
013224279	ND	ND	ND	ND	ND	ND	ND

Table 4.4 Ship Model Regression Results

total and specific NIIN items processed per month show an inconsistent, but strong, relationship with average repair time. One can positively state that the strongest relationship in the shore model, based upon the regression, is between average repair time and specific NIIN items processed per month.

The ship model returned inconclusive results because of a lack of useable data. The tech rep visit appears to have an appreciable negative effect on average repair time, while the total and specific NIIN items processed per month have an inconclusive, but strong positive or negative relationship with average repair time, depending upon the specific NIIN item.

A most interesting observation is that the learning curve effect does not consistently appear in the results of either of these analyses. The reason for this is unknown, but it would be an interesting subject for further investigation.

V. CONCLUSIONS AND RECOMMENDATIONS

A. THE PRIMARY RESEARCH QUESTION: CONCLUSION

Can we measure the effect of ETS (tech rep visits) on the throughput rate of aviation depot level repairable items serviced by automatic test equipment (ATE)?

The shore model was shown to be somewhat effective in providing a measure of the effect that the tech rep has on throughput. The correlations and regressions performed in Chapter IV show a <u>definite negative relationship between average repair time and tech rep hours worked</u>. The actual contribution of the tech rep's time to the variation of average repair time is small, based on the magnitude of the correlation values, the coefficient values from the regressions, and the values of the R squares. The significance level of the data indicates that the effect is not random in many instances, although it does not conclusively rule out random effects.

The ship model was largely unsuccessful in measuring the effects of the tech rep visit on the average repair time, due to the lack of a large enough data set. The results do point to a negative relationship between average repair time and tech rep visits to the ship, but are not dependable.

As mentioned in the previous chapter, a larger, more varied data set may yield different results. New factors for analysis as independent variables in the models may also prove interesting and make the ship model more significant with respect to measurement of tech rep effects.

It is also possible that the tech rep just does not have any measurable effect upon shipboard Automatic Test Equipment (ATE) operations. Unlike the shore station, which has a tech rep present almost all the time, the tech rep is rarely aboard ship. When he is aboard ship he may be concentrating on training (his primary mission), which may not have a

noticeable effect on average repair times. If this is so, then it might prove to be of greater worth to do a study on the effects this training has on maintenance throughput.

B. THE SUBSIDIARY RESEARCH QUESTION: CONCLUSION

Can a tech rep value-added quantification be made using the developed measurement method?

Using the shore model results it is possible to infer that the tech rep enables one to reduce the inventory of locally carried Aviation Depot Level Repairables (AVDLRs). The relationships demonstrated in Chapter IV are not strong enough to base reductions of inventory on, but it can be said that the contribution of the tech rep at the shore station may enable the shore station to get by with one or two less of certain items (as in getting by during shortages of certain items). The ability of a tech rep to forestall or eliminate the ordering of one or two high cost items per year may justify the expense of employment. With the cost of many components over the $50,000 per item mark, it does not take very many of these items to exceed the tech rep employment cost (maybe two or three items per tech rep).

The ship model results infer similar benefits for the two NIIN item cases studied, but a general statement cannot be made because of the size of the data set. It is reasonable to assume that similar results would be found on other ships and with other test bench types.

C. COMMENTS

It is possible that when called out to perform a specific "troubleshoot and repair" job the tech rep may have little or no impact on personnel operating capabilities. The extent of training accomplished and retained by the operators also of course depends on the abilities of the operators and the tech rep's training capabilities. These were not accounted for in

the model used.

The results of the models used in this thesis should encourage further study on the use of this or any other technique for measure of the effect of the tech rep on the productivity of a work center. The very large number of factors affecting the production in a work center make selection and entry into a regression model a difficult and somewhat hit or miss task. Data problems also have effects on the outcome of this or any other study using maintenance information. The small number of tech rep visits to the ships may make a different approach necessary.

D. RECOMMENDATIONS FOR FURTHER RESEARCH

As discussed above, even though the shore model did show some significant relationship between tech rep hours and average repair times there are a lot of avenues left to be researched in this area. Possible areas for further research are:

- Enhancing the shore and ship models with additional independent variables, determined by a detailed on-site investigation of the pertinent work center;
- Investigation into the use of a completely different mathematical or statistical technique to measure the possible effect of a tech rep on production;
- Analysis of a larger data set from the NALDA database or another data base;
- Investigation into the training effects of the tech rep visit. It is intuitive that the training and maintenance skills imparted by the tech rep must last for some period of time;
- Development of a specific methodology to measure the inventory effects of the tech rep;
- Investigation of the effects of tech reps in other military communities such the submarine or surface forces;

- Investigation of tech rep effects in the civilian sector;

APPENDIX A. SHORE MODEL DATA

The shore-based Electro Optical Test Set (EOTS) work center data used in the analysis are presented here. Each specific NIIN is presented in its own table, containing the dependent variable Y_{RT} (average repair time), and the independent variables X_1 (tech rep hours), X_2 (specific NIIN items processed per month, and X_3 (total NIIN items processed per month.

Shore Model
NIIN Item 011861629

Year / Month	Ave Rep Time (Days)	Tech Rep Hours Per Month (X1)	Specific NIIN Items Processed Per Month (X2)	Total NIIN Items Processed Per Month (X3)
9308	21	160	2	4
9309	46	160	5	17
9310	28	90	3	17
9311	26	140	7	25
9312	38	40	7	25
9401	47	120	18	47
9402	56	160	9	35
9403	28	40	6	23
9404	22	160	5	30
9405	26	120	4	16
9406	59	0	10	29
9407	56	140	6	21
9408	49	264	6	26
9409	23	320	8	30
9410	30	328	9	26
9411	30	280	4	21
9412	38	120	6	19
9501	60	160	7	31

Shore Model
NIIN Item 011884089

Year / Month	Ave Rep Time (Days)	Tech Rep Hours Per Month (X1)	Specific NIIN Items Processed Per Month (X2)	Total NIIN Items Processed Per Month (X3)
9309	5	160	2	17
9310	21	90	3	17
9311	10	140	3	25
9312	4	40	2	25
9401	26	120	6	47
9402	5	160	1	35
9403	48	40	4	23
9404	8	160	4	30
9405	30	120	4	16
9406	7	0	1	29
9407	4	140	2	21
9409	3	320	2	30
9410	9	328	1	26
9411	4	280	1	21
9412	22	120	1	19
9501	6	160	3	31

Shore Model
NIIN Item 011468298

Year / Month	Ave Rep Time (Days)	Tech Rep Hours Per Month (X1)	Specific NIIN Items Processed Per Month (X2)	Total NIIN Items Processed Per Month (X3)
9312	36	40	1	25
9401	23	120	1	47
9402	30	160	2	35
9403	15	40	1	23
9404	7	160	2	30
9405	11	120	2	16
9406	12	0	3	29
9409	12	320	1	30
9412	48	120	1	19

Shore Model
NIIN Item 012900767

Year / Month	Ave Rep Time (Days)	Tech Rep Hours Per Month (X1)	Specific NIIN Items Processed Per Month (X2)	Total NIIN Items Processed Per Month (X3)
9309	5	160	1	17
9310	9	90	2	17
9312	13	40	3	25
9401	13	120	3	47
9402	12	160	3	35
9403	16	40	2	23
9404	36	160	3	30
9405	14	120	1	16
9406	54	0	2	29
9407	20	140	2	21
9409	20	320	6	30
9410	26	328	3	26
9411	9	280	7	21
9412	18	120	2	19
9501	9	160	5	31

Shore Model
NIIN Item 013174521

Year / Month	Ave Rep Time (Days)	Tech Rep Hours Per Month (X1)	Specific NIIN Items Processed Per Month (X2)	Total NIIN Items Processed Per Month (X3)
9309	17	160	1	17
9310	24	90	1	17
9311	46	140	5	25
9312	62	40	3	25
9401	40	120	4	47
9402	47	160	6	35
9403	67	40	3	23
9404	24	160	4	30
9405	15	120	2	16
9406	48	0	2	29
9407	21	140	4	21
9408	11	264	8	26
9409	15	320	4	30
9410	20	328	6	26
9411	11	280	3	21
9412	9	120	4	19
9501	17	160	7	31

Shore Model
NIIN Item 011861418

Year / Month	Ave Rep Time (Days)	Tech Rep Hours Per Month (X1)	Specific NIIN Items Processed Per Month (X2)	Total NIIN Items Processed Per Month (X3)
9311	18	140	2	25
9401	20	120	5	47
9404	12	160	3	30
9406	37	0	2	29
9407	26	140	1	21
9408	14	264	3	26

Shore Model
NIIN Item 013224279

Year / Month	Ave Rep Time (Days)	Tech Rep Hours Per Month (X1)	Specific NIIN Items Processed Per Month (X2)	Total NIIN Items Processed Per Month (X3)
9309	14	160	2	17
9311	8	140	2	25
9401	24	120	3	47
9402	18	160	2	35
9403	17	40	2	23
9404	15	160	2	30
9405	12	120	3	16
9406	10	0	3	29
9407	11	140	1	21
9410	18	328	2	26
9411	12	280	1	21
9412	30	120	1	19
9501	15	160	3	31

Shore Model
NIIN Item 011861619

Year / Month	Ave Rep Time (Days)	Tech Rep Hours Per Month (X1)	Specific NIIN Items Processed Per Month (X2)	Total NIIN Items Processed Per Month (X3)
9310	15	90	0	17
9312	2	40	0	25
9404	5	160	2	30
9406	8	0	3	29
9409	6	320	0	30
9412	2	120	1	19
9501	9	160	3	31

Shore Model
NIIN Item 011861430

Year / Month	Ave Rep Time (Days)	Tech Rep Hours Per Month (X1)	Specific NIIN Items Processed Per Month (X2)	Total NIIN Items Processed Per Month (X3)
9309	23	160	2	17
9312	15	40	4	25
9401	12	120	5	47
9404	15	160	3	30
9406	13	0	2	29
9407	10	140	2	21
9408	24	264	1	26
9409	42	320	2	30

Shore Model
NIIN Item 012711091

Year / Month	Ave Rep Time (Days)	Tech Rep Hours Per Month (X1)	Specific NIIN Items Processed Per Month (X2)	Total NIIN Items Processed Per Month (X3)
9311	29	140	1	25
9404	13	160	2	30
9406	6	0	1	29
9407	4	140	1	21
9408	12	264	1	26

Shore Model
NIIN Item 011872208

Year / Month	Ave Rep Time (Days	Tech Rep Hours Per Month (X1)	Specific NIIN Items Processed Per Month (X2)	Total NIIN Items Processed Per Month (X3)
9308	22	160	1	4
9309	13	160	0	17
9311	18	140	2	25
9312	9	40	2	25
9402	38	160	1	35
9403	38	40	3	23
9406	23	0	1	29
9407	20	140	1	21
9408	30	264	2	26

Shore Model
NIIN Item 012623221

Year / Month	Ave Rep Time (Days)	Tech Rep Hours Per Month (X1)	Specific NIIN Items Processed Per Month (X2)	Total NIIN Items Processed Per Month (X3)
9309	73	160	2	17
9310	44	90	2	17
9311	48	140	1	25
9401	51	120	2	47
9409	44	320	2	30
9410	9	328	1	26

Shore Model
NIIN Item 013174556

Year / Month	Ave Rep Time (Days)	Tech Rep Hours Per Month (X1)	Specific NIIN Items Processed Per Month (X2)	Total NIIN Items Processed Per Month (X3)
9309	7	160	1	17
9310	26	90	1	17
9311	22	140	1	25
9312	13	40	1	25
9401	19	120	0	47
9402	36	160	5	35
9403	12	40	1	23
9407	76	140	1	21
9408	22	264	4	26
9410	25	328	3	26
9411	9	280	2	21
9412	21	120	1	19

APPENDIX B. SHIP MODEL DATA

The ship-based Electro Optical Test Set (EOTS) work center data used in the analysis are presented here. Each specific NIIN is presented in its own table, containing the dependent variable Y_{RT} (average repair time), and the independent variables X_1 (tech rep visits), X_2 (specific NIIN items processed per month, and X_3 (total NIIN items processed per month.

Ship Model
NIIN Item 011861629

Ship: Kitty Hawk Vinson Lincoln	Year / Month	Ave Rep Time (Days)	Tech Rep Visits (X1)	Specific NIIN Items Processed Per Month (X2)	Total NIIN Items Processed Per Month (X3)
KH	9403	27	0	5	12
KH	9407	56	0	2	9
KH	9408	27	0	2	6
KH	9409	24	0	2	8
KH	9410	43	0	3	10
V	9402	9	1	2	3
V	9404	7	1	2	6
V	9405	9	0	4	9
V	9406	8	0	1	7
V	9407	10	0	2	8
V	9408	11	0	1	2
L	9308	46	0	4	7
L	9309	64	0	4	12
L	9310	37	0	7	14
L	9311	14	0	1	6

Ship Model
NIIN Item 011884089

Ship: Kitty Hawk Vinson Lincoln	Year / Month	Ave Rep Time (Days)	Tech Rep Visits (X1)	Specific NIIN Items Processed Per Month (X2)	Total NIIN Items Processed Per Month (X3)
KH	9403	19	0	2	12
KH	9411	7	0	2	9
V	9407	4	0	1	8
L	9309	2	0	1	12

No tech rep visits

Ship Model
NIIN Item 011468298

Ship: Kitty Hawk Vinson Lincoln	Year / Month	Ave Rep Time (Days)	Tech Rep Visits (X1)	Specific NIIN Items Processed Per Month (X2)	Total NIIN Items Processed Per Month (X3)
KH	9410	75	0	1	10
KH	9411	69	0	3	9
V	9406	3	0	1	7
V	9407	5	0	1	8
L	9310	55	0	1	14
L	9311	42	0	3	6

No tech rep visits

Ship Model
NIIN Item . 012900767

Ship: Kitty Hawk Vinson Lincoln	Year / Month	Ave Rep Time (Days)	Tech Rep Visits (X1)	Specific NIIN Items Processed Per Month (X2)	Total NIIN Items Processed Per Month (X3)
KH	9407	34	0	2	9
KH	9408	48	0	2	6
KH	9410	30	0	1	10
L	9309	27	0	2	12
L	9310	4	0	0	14
L	9411	39	0	1	1

No tech rep visits

Ship Model
NIIN Item 013174521

Ship: Kitty Hawk Vinson Lincoln	Year / Month	Ave Rep Time (Days)	Tech Rep Visits (X1)	Specific NIIN Items Processed Per Month (X2)	Total NIIN Items Processed Per Month (X3)
KH	9403	15	0	1	12
KH	9404	15	1	2	2
KH	9407	32	0	2	9
KH	9409	56	0	1	8
KH	9411	58	0	2	9
V	9311	40	0	1	1
V	9404	11	1	1	6
V	9406	41	0	2	7
V	9407	4	0	2	8
L	9308	27	0	3	7
L	9309	65	0	4	12
L	9310	20	0	3	14
L	9311	8	0	1	6
L	9312	45	0	1	1
L	9501	13	0	0	0

Ship Model
NIIN Item 013224279

Ship: Kitty Hawk Vinson Lincoln	Year / Month	Ave Rep Time (Days)	Tech Rep Visits (X1)	Specific NIIN Items Processed Per Month (X2)	Total NIIN Items Processed Per Month (X3)
KH	9407	46	0	3	9
KH	9409	27	0	2	8
KH	9410	67	0	1	10
KH	9411	44	0	1	9
L	9310	45	0	2	14

No tech rep visits

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